MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2018/2019

EEE2146 – MICROELECTRONIC CIRCUIT ANALYSIS AND DESIGN

(All sections / Groups)

12 MARCH 2019

9:00 AM to 11:00 AM

(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This examination paper consists of 7 pages with 4 questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) Compute the transistor base current, I_B, emitter current, I_E, emitter voltage, V_E and base voltage, V_B (with respect to ground) of the circuit shown in Figure Q1. Given that V_{CC} = 10 V and the transistor $V_{BE(active)}$ = 0.7 V, current gain β = 100 and early voltage $V_A = \infty$. Note that, R_B = 150 kΩ, R_E = 1 kΩ, R_L = 2 kΩ, R_S = 50 Ω. [7 marks]

(b) Draw the mid-band AC small-signal equivalent circuit of the amplifier circuit in Figure Q1 using the simplified hybrid-π model. [5 marks]

(c) From the small-signal equivalent circuit, determine;
(i) the small signal input resistance, R_{IN}, [5 marks]
(ii) the voltage gain, $A_V = \frac{V_O}{V_{IN}}$, [4 marks]
(iii) and finally, the overall voltage gain, $G_V = \frac{V_O}{V_S}$. [4 marks]
Note that, voltage equivalence of temperature V_T = 26 mV.

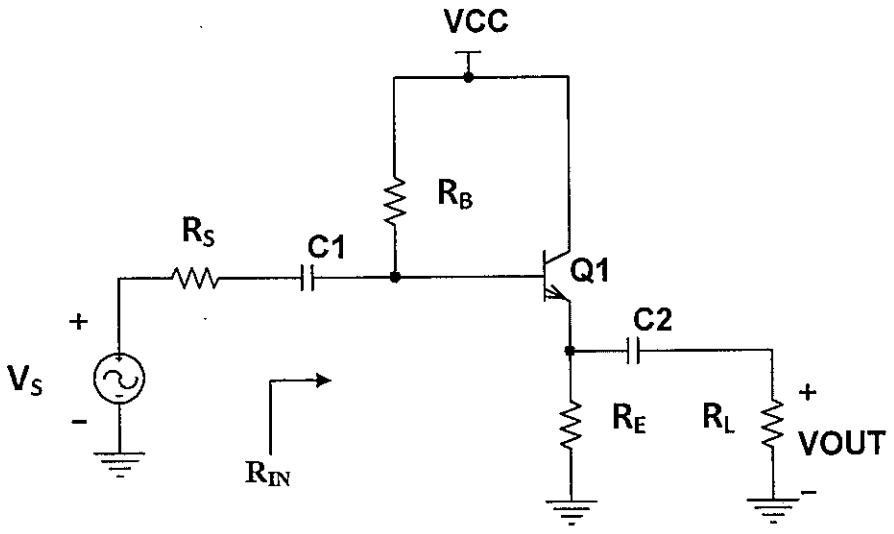

Figure Q1

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Question 2

The circuit shown in Figure Q2 is a common source amplifier. The NMOS transistor has V_t = 1.5 V, $k'_n(W/L)$ = 1 mA/V^2 and V_A = 65 V. The biasing current is Id = 0.5 mA. Note that, VDD = VSS = 10 V, R_G = 10 MΩ, R_D = 10 kΩ, R_L = 10 kΩ and R_{sig} = 50 Ω.

(a) From the DC analysis, by assuming the transistor is operating in saturation region, determine the overdrive voltage V_{OV}, the DC gate-source voltage V_{GS}, the DC source voltage V_S and the DC drain voltage V_D. Note that, the DC gate current, I_G = 0 A. [7 marks]

(b) Draw a mid-band AC small-signal equivalent circuit for the circuit shown in Figure Q2 using the simplified hybrid-π model. [5 marks]

(c) Refer to the small-signal equivalent circuit in part (b), determine;
(i) the small-signal input resistance, R_{IN}, [1 mark]
(ii) the small signal output resistance R_{OUT}, [3 marks]

(iii) the small-signal voltage gain, $A_v = \frac{v_o}{v_{in}}$, and [6 marks]

(iiii) the overall small-signal voltage gain, $G_v = \frac{v_o}{v_{sig}}$. [3 marks]

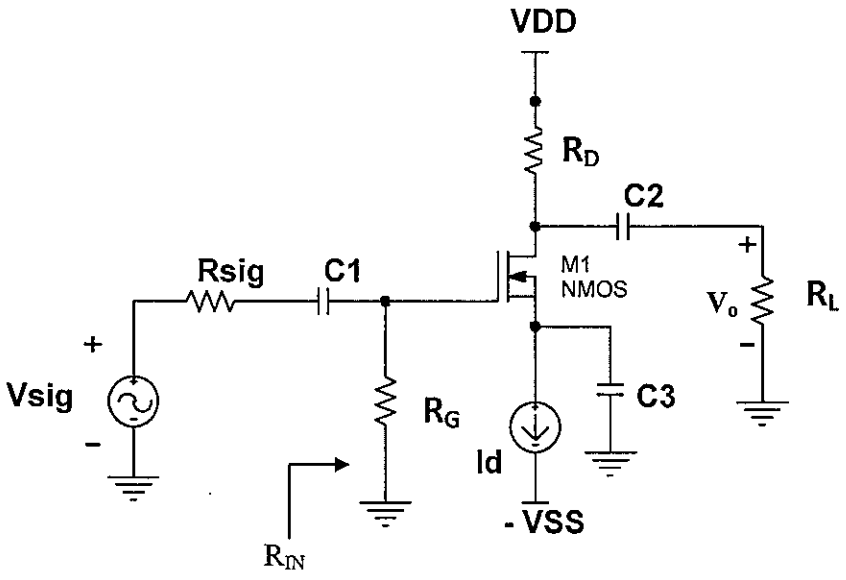

Figure Q2

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Question 3

Figure Q3 shows a differential amplifier with a current mirror as its biasing element.

(a) Assume all transistors are identical and have the current gain β, show that the biasing current I_Q has the following expression: [7 marks]

$$I_Q = \frac{I_{REF}}{\left(1 + \frac{2}{\beta(\beta+1)}\right)}$$

(b) Design the differential amplifier as shown in Figure Q3 by finding the values of R_C, where $R_{C1} = R_{C2} = R_C$. The biasing current I_Q = 1 mA and small-signal differential-mode voltage gain A_d = -200 with V_{CC} = 10 V and V_{EE} = -10 V. Assume that all the transistors are identical and their current gain β = 200, $V_{BE(active)}$ = 0.7 V and early voltage V_A = ∞. Use voltage equivalence of temperature V_T = 26 mV. [8 marks]

(c) From Figure Q3,
(i) draw the AC equivalent circuit for the differential amplifier ONLY, [2 marks]
(ii) then, draw the differential-mode half circuit, and [2 marks]
(iii) its corresponding small signal equivalent circuit. [2 marks]
(iv) Finally, prove that the small-signal differential-mode voltage gain of the differential amplifier shown in Figure Q3 is as follows; [4 marks]

$$A_d = \frac{v_{od}}{v_{id}} = -g_m\left(R_C \| r_o\right).$$

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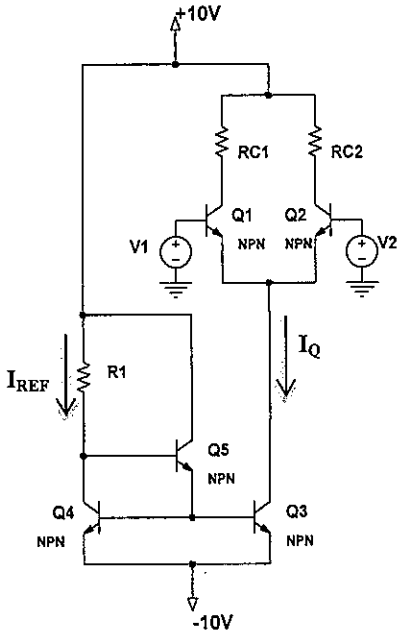

Figure Q3

Question 4

(a) Higher cut off frequencies are mostly affected by internal capacitance, C_π and C_μ. From common emitter amplifier circuit shown in Figure Q4(a), state the equation for;

i. the Thevenin's equivalent resistance seen by C_π only, $R_{C\pi}$ and [1 mark]

ii. the Thevenin's equivalent resistance seen by C_μ only, $R_{C\mu}$. [3 marks]

iii. Then, identify the high 3-dB cut off frequency, f_H for this circuit. The parameters of this circuit are $V_{CC} = 5$ V, $R_B = 16.5$ kΩ, $R_C = 10$ kΩ, $R_E = 5$ kΩ, $R_s = 50\Omega$, $R_L = 10$kΩ, $C_\pi = 10$ pF, $C_\mu = 5$ pF and $\beta = 100$. The circuit is biased with $I_C = 0.2$mA. [8 marks]

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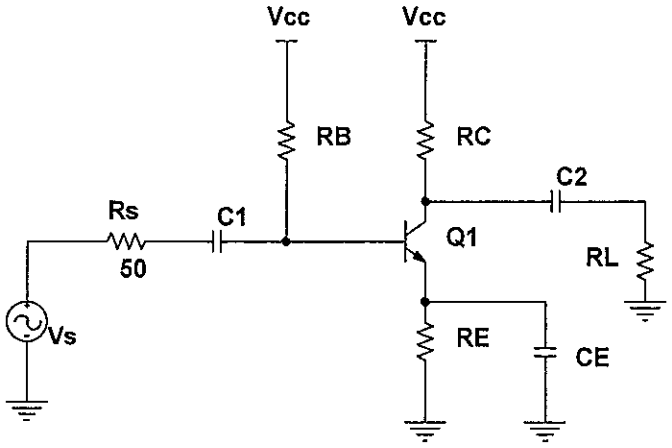

Figure Q4(a)

(b) The transresistance amplifier shown in Figure Q4 (b) is a shunt-shunt feedback amplifier.

(i) Draw the feedback (β) network ONLY and find the equation for input impedance, $R_{i\beta}$, output impedance, $R_{o\beta}$ and feedback factor, β. [5 marks]

(ii) Draw the modified equivalent circuit for the circuit to include $R_{i\beta}$, $R_{o\beta}$ and β. [2 marks]

(iii) Derive the equation for input impedance, R_{ie}, output impedance, R_{oe} and gain, $A_e = \frac{V_o}{I_s}$. [6 marks]

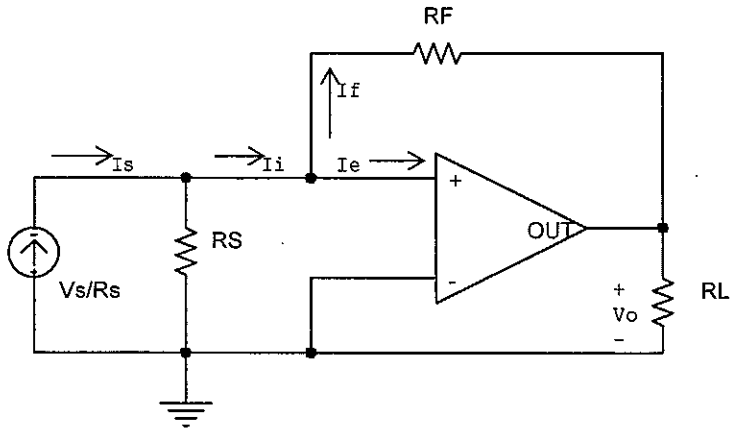

Figure Q4(b)

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Appendix: Useful formula

$$\beta = \frac{I_C}{I_B}$$

$$\alpha = \frac{I_c}{I_E}$$

$$\alpha = \frac{\beta}{\beta+1}$$

$$\beta = \frac{\alpha}{1-\alpha}$$

$$r_e = \frac{V_T}{I_E}$$

$$\alpha = \frac{r_e}{g_m}$$

$$r_\pi = (\beta + 1)r_e$$

$$V_T = \frac{kT}{q} \approx 26mV$$

$$I_C = I_S\left(\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right)\left(1 + \frac{V_{CE}}{V_A}\right)$$

$$g_m = \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{V_T}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{\beta V_T}{I_C} = \frac{V_T}{I_B}$$

$$r_o = \frac{1}{\partial I_C / \partial V_{CE}} = \frac{V_A}{I_C}$$

$$g_m v_\pi = \beta i_b$$

$V_{DS} < V_{GS} - V_t$:

$$I_D = k'\left(\frac{W}{L}\right)\left[(V_{GS} - V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right]$$

$V_{DS} > V_{GS} - V_t$:

$$I_D = \frac{k'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_t)^2$$

$V_{DS} > V_{DS(SAT)}$:

$$I_D = \frac{k'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_t)^2(1 + \lambda V_{DS})$$

$$V_A = V_M = L_{eff}\left(\frac{dX_d}{dV_{DS}}\right)^{-1} = \frac{1}{\lambda}$$

$$r_o = \frac{V_A}{I_D}$$

$$\phi_f = \frac{kT}{q}\ln\left(\frac{N_A}{n_i}\right)$$

$$\gamma = \frac{\sqrt{2q\varepsilon N_A}}{C_{ox}}$$

$$V_t = V_{to} + \gamma\left(\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f}\right)$$

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$$

$$k' = \mu_n C_{ox}$$

$$V_{OV} = V_{GS} - V_t$$

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = k'\frac{W}{L}V_{OV} = \frac{2I_D}{V_{OV}}$$

$$C_{gs} = C_{gd} = \frac{C_{ox}WL}{2}$$

$$I_D = I_t\frac{W}{L}\exp\left(\frac{V_{OV}}{nV_T}\right)\left[1 - \exp\left(\frac{-V_{DS}}{V_T}\right)\right]$$

End of Paper